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Tebuthiuron Persistence in

Intermountain Soils

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TEBUTHIURON PERSISTENCE IN INTERMOUNTAIN SOILS

FINAL REPORT

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SUMMARY

Tebuthiuron {N-[5-(1,1 dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea} pellets containing 20 and 40% active ingredient (ai) were placed on the surface of three soils in Utah. Soil collections were made at four or five post-application dates from 20 to 370 days and from 12 combinations of depth and distance from the point of pellet placement. Soil samples were collected from three depths (0 to 3, 3 to 12, and 12 to 30 cm) and at four distances (0, 10, 20, and 30 cm). Soil samples were analyzed for tebuthiuron residues using High Performance Liquid Chromatography (HPLC) with an ultraviolet detector.

Vertical and lateral movement, and persistence were influenced by precipitation, clay content, and organic matter content of the soil. Lateral movement of tebuthiuron was less on high organic matter soils compared to low organic matter soils. Tebuthiuron movement away from 40% pellets was greater than from the 20% pellets. Downward movement of tebuthiuron increased with low soil organic matter and more concentrated pellet formulations. Tebuthiuron (formulated as 40% pellets) disappearance in the surface 3 cm of soil under the pellet was best explained by the exponential regression equation:

$$Y = bX^a$$

where Y is the tebuthiuron concentration in ppmw and X is time (days) after pellet application, b is 1.43×10^6, and a is -1.964 (r^2=0.92). Negative exponential regression equations describing tebuthiuron disappearance in the surface 3 cm of soil under the pellet were developed for each soil and formulation. The coefficient of determination (r^2) values for these equations ranged from 0.92 to 0.99. Tebuthiuron disappearance in high organic matter soils was more rapid than in low organic matter soils. The highest tebuthiuron residues occurred within 2 cm of the pellet. Surface-soil residuals under 40% pellets were 1,843 ppm 37 days after treatment at one of the three sites. However, this concentration was present in only a small area under each pellet. Data collected during this study indicate that an application of 40% tebuthiuron pellets at 1.1 kg ai/ha would leave a residue on 17 to 38% of the treated area, depending on the soil organic matter content.

Tebuthiuron residues reported in this research are much higher than those reported by other investigators. This is probably because the other studies reported concentrations from random soil samples collected in treated areas. Those samples contained soil from immediately under pellets as well as from between pellets. The size of the untreated area between pellets would vary with pellet formulation, pellet size, and application rate. The resulting mixture of soil would have lower tebuthiuron concentrations than soil collected from immediately under the pellet. This study reports residues from soil collected immediately under and around tebuthiuron pellets. This different sampling approach as well as variations in soil characteristics and climatic conditions probably account for much of the variation in tebuthiuron concentrations.

INTRODUCTION

Tebuthiuron is a substituted-urea type herbicide formulated as a wettable powder, granule, or extruded pellet. Extruded pellets containing 20 or 40% ai have recently (since 1979) been register - ed for rangeland use in Arizona, Arkansas, Colorado, Idaho, Kansas, Missouri, Montana, New Mexico, Nevada, Oklahoma, Oregon, Texas, Utah, Washington, and Wyoming.

Tebuthiuron is a photosynthesis inhibitor which is more readily absorbed by plant roots than by foliage (Steinert and Stritzke 1977). Typical symptoms of tebuthiuron phytotoxicity are chlorosis of interveinal leaf tissue followed by necrosis and leaf drop. As a soil-active herbicide, application time is not so dependent on a specific phenological stage of plant development as with conventional foliar-applied herbicides. This attribute makes it attractive to resource managers. Most effective results follow application just prior to the greatest rainfall period. Movement into the soil profile results in maximum amounts of tebuthiuron being available for absorption and translocation during the period of maximum plant growth.

Aerially applied broadcast applications of tebuthiuron pellets are reportedly effective for control of mountain big sagebrush (*Artemisia tridentata* ssp.*vaseyana*) (Clary et al. 1985a), Utah juniper (*Juniperus osteosperma*) (Clary et al. 1985a), and Gambel oak (*Quercus gambelii*) (Clary et al. 1985b). Tebuthiuron has proven ineffective in controlling western juniper (*J. occidentalis*) (Britton and Sneva 1981), and eastern red cedar (*J. virginiana*) (Scifres et al. 1981). Efficacy and persistence of soil-applied herbicides are functions of application rate, timeliness and extent of post-application rainfall, soil organic matter and clay content. Previous lab (Chang and Stritzke 1977) and greenhouse (Duncan and Scifres 1983) studies indicated tebuthiuron is relatively immobile in the soil and may be quite persistent. Field observations of tebuthiuron treated rangeland indicate that significant residues may persist in soils for 2 to 4 years.

Pelleted herbicides have several advantages compared to foliar-active sprays for rangeland use. Most important among these advantages are reduced drift potential, negligible volatilization hazard, and a longer application season. Soil-active herbicides such as tebuthiuron depend on rainfall for transport into the root zone. Activity of a soil-active herbicide is regulated by leaching, chemical degradation, microbial decomposition, and/or adsorption onto the soil colloids (Kearney and Kaufman 1969). Since these processes reduce the amount of herbicide available for uptake by plants, an understanding of soil-herbicide interactions is of practical importance to range resource managers, especially as they influence decisions concerning herbicide application rate. Persistence and activity of tebuthiuron in soils has important implications in areas to be reseeded following application.

Several reports (Hance 1965, Dubey and Freeman 1969, Kearney and Kaufman 1969) have indicated organic matter to be the single most important soil characteristic in adsorption of substituted-urea herbicides. Chang and Stritzke (1977) reported tebuthiuron mobility to be greater in soils with low organic matter and clay contents. They found 40% of the tebuthiuron was adsorbed when applied to a soil with 4.8% organic matter. Bovey et al. (1982) determined that tebuthiuron residues at 30 cm persisted for more than 2 years in a fine sandy loam soil in Texas.

However, Harris and Warren (1964) indicated that organic matter may be responsible for more adsorption of herbicides by some soils, and clay more important in others, since soil compositions vary so greatly. Sheets (1958) and Geissbuhler et al. (1963) reported varying amounts and types of clay minerals could influence adsorption of phenylurea herbicides, particularly in soils with relatively low organic matter. Duncan and Scifres (1983) stated that the potential for tebuthiuron phytotoxicity to huisache (*Acacia farnesiana*) was greatly diminished in soils containing more than 30% clay.

Using a sandy loam soil with 0.3% organic matter, Steinert and Stritzke (1977) found Japanese brome (*Bromus japonicus*) to be the most susceptible of nine plant species tested. This

evaluation was based on GR_{50} values (the amount of herbicide required to reduce the fresh weight of treated plants by 50%). Japanese brome, in this soil with low clay and organic matter contents, had a GR_{50} value of 0.016 ppmw. They also indicated that responses of established plants appeared to differ from the responses of seedlings. Masters and Scifres (1984) found that shoot and root weights of several grasses tended to decrease, and that percent grass mortality, in greenhouse studies using aeolian sand, increased as tebuthiuron concentrations increased from 0 to 0.25 ppmw. These studies purposely used soils with low clay and organic matter contents to establish minimum tebuthiuron concentrations required for growth reduction or mortality under conditions most likely to cause problems.

Soils with higher clay and organic matter contents will require much higher concentrations for problems to result. For example, tebuthiuron concentrations of 1 or 2 ppm killed huisache after 287 days, regardless of soil, whereas 0.12 or 0.25 ppm killed huisache only when applied to soils with less than 15% clay and less than 2.5% organic matter (Duncan and Scifres 1983). Soils with 4.8% organic matter have reportedly adsorbed as much as 40% of the applied tebuthiuron Chang and Stritzke 1977). However, too little data is available to confidently perdict the tebuthiuron concentration at which problems with specific plant species will begin to appear.

Bovey et al. (1982) using wheat bioassays of treated soil stated that the long residual life and effectiveness of tebuthiuron on certain weed and brush species make it a highly successful herb - icide. However, these same attributes may inhibit the growth of desirable vegetation, especially if seeding or vegetative propagation is attempted too soon after treatment.

METHODS AND EXPERIMENTAL DESIGN

Tebuthiuron formulated as 20 and 40% extruded pellets was placed on loam soils at two field locations in randomized complete block designs near Ephraim and Tintic, Utah[1]. Pellet placement locations were permanently marked; enabling future soil sampling under and around the point of pellet placement.

These studies were initiated to investigate the movement and dissipation of tebuthiuron from the immediate location of pellets containing either 20 or 40% active ingredients (ai). Individual pellets weighed 168 ± 3 mg and 206 ± 1 mg for the 20 and 40% pellets, respectively.

Soil collections were made from 12 combinations of depth and distance from the point of pellet placement. Soil samples were collected from three depths (0 to 3, 3 to 12, and 12 to 30 cm) and at four distances (0, 10, 20, and 30 cm). Duplicate subsamples were combined to produce each of the samples to be analyzed in the lab.

Soil samples were placed in polyethylene bags and frozen until laboratory extractions and analyses were conducted. Prior to freezing, soil samples were air-dried and ground to pass through a 2 mm sieve. The entire soil sample, at least 50 g, was throughly mixed prior to extraction.

Ephraim Study Area. Tebuthiuron pellets were applied to the interspaces of a Utah juniper community on April 13, 1984. The soil under the juniper trees, with its presumably higher organic matter content, was avoided at this study area. Soil collections were made on May 3, May 23, June 12, July 2, October 10, 1984; and May 4, 1985.

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[1]The authors acknowledge the assistance of the Utah Division of Wildlife Resources and the Range Science Department at Utah State University. Their assistance in locating study areas and in providing precipitation data is gratefully appreciated.

Tintic Study Area. The Tintic study area is a basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) site where the sagebrush plants were removed at the soil surface. Tebuthiuron pellets of each formulation were placed on the soil under the former sagebrush canopy and in the interspaces, on May 5, 1984. The soil under the sagebrush canopies has a much higher surface soil organic matter content (Table 1) than the soil in the interspaces, providing an excellent opportunity for comparing tebuthiuron movement and persistence under identical soil texture and precipitation conditions. The sagebrush plants were removed at ground level so precipitation amount and intensity would be similar on the tebuthiuron pellets placed on both soils. Soil collections, for future laboratory analyses, were made on May 25, June 12, July 22, October 30, 1984; and May 5, 1985.

Laboratory Analysis. Tebuthiuron was sequentially extracted from soil with a mixture of water and methanol, followed by boiling 3N HCl. An aliquot of the extract was purified by liquid-liquid partitioning and alumina column chromatography. The purified extracts were concentrated for measurement by comparison with a standard solution using HPLC and an ultra-violet absorbance detector at a 254 nm wavelength (West and Burger 1981).

Statistical Analysis. Based on recovery samples fortified with 0.1 to 5,000 ppmw of technical tebuthiuron, average recovery was 91.3 ± 4.1% and sensitivity was 0.1 ppm. Tebuthiuron residue concentrations from the soil samples at all sampling dates, distances and depths within each combination of study area and pellet formulation were subjected to analysis of variance. Mean separation was conducted using Duncan's new multiple range test. This resulted in six separate tables listing tebuthiuron residue concentrations at each combination of sampling date, depth and distance from the pellet.

Tebuthiuron concentrations (ppm) in the surface 3 cm of soil under the pellet and at each combination of pellet formulation and soil were subjected to linear and quadratic regression. Tebuthiuron concentration was used as the dependent variable; cumulative precipitation and the number of days after pellet application were used (in separate equations) as the independent variable.

RESULTS

The tebuthiuron pellets lost their original structure by the first sampling date as a result of rainfall, but were visible on the soil surface at both study areas. Precipitation from the application date to the first sampling date was 7.16 cm at the Ephraim study area and 4.98 cm at the Tintic study area (Table 2). Total precipitation over the 350 to 370 day period was quite similar, varying from 46 to 50 cm (Table 2).

At the Ephraim study area, the highest tebuthiuron residues 20 days after treatment, were within 2 cm of the pellet and in the surface 3 cm of soil. Tebuthiuron residues were 499 ppm under the 20% pellets (Table 3) and 1,254 ppm under the 40% pellets (Table 4). The 40% pellets were approximately 19% larger than the 20% pellets, in addition to containing twice as much tebuthiuron. These factors account for most of the difference in initial soil residues.

Data from the Ephraim location indicate little lateral movement of tebuthiuron into the 30 cm area, except at the 12- to 30-cm depth under the 40% pellets (Table 4). Significant tebuthiuron residues did not appear at this depth-distance combination for at least 6 months after treatment.

At the Ephraim location, downward movement of tebuthiuron from 20% pellets was not evident for 40 and 78 days at the 3- to 12-cm and 12- to 30-cm depths, respectively (Table 3). However, at the same depths, tebuthiuron residues appeared at 20 and 40 days under the 40% pellets (Table 4). The tebuthiuron appeared to move down and slightly outward. At the lowest

soil layer collected, tebuthiuron residues were often greater at the 10 and 20 cm distances than directly under the pellet.

At the Tintic study area, the highest tebuthiuron residues occurred within 2 cm of the pellet and in the surface 3 cm of soil 37 days after treatment. Tebuthiuron residues in the low organic matter soil were 573 ppm under the 20% pellets (Table 5) and 1,843 ppm under the 40% pellets (Table 6). In the high organic matter soil the tebuthiuron residues were 768 ppm under the 20% pellets (Table 7) and were 1,652 ppm under the 40% pellets (Table 8).

Lateral movement of tebuthiuron residues was generally reduced on the high organic matter soils compared to the low organic matter soils. Tebuthiuron movement away from the 40% pellets was greater than from the 20% pellets. Downward movement of tebuthiuron residues increased with low soil organic matter and more concentrated pellet formulations.

Attempts at describing tebuthiuron disappearance in the surface 3 cm of soil using linear regression were unsuccessful. Coefficients of correlation ranged from 0.44 to 0.78. However, negative exponential regression provided a more reliable description of tebuthiuron disappearance in this study. Cumulative precipitation proved to be a less precise independent variable for predicting tebuthiuron disappearance than the number of "days between application and soil collection". All regression equations in this report use "days" as the independent variable. Equations fitting data from each of the three soils and two pellet formulations and overall equations for each pellet formulation are found in Table 9.

Tebuthiuron disappearance in the surface 3 cm of soil under the 40% pellets, in all three soils, was best explained by the exponential regression equation:

$$Y = bX^a$$

where Y is the tebuthiuron concentration in ppmw and X is time (days) after pellet placement, b is 1.43×10^6, and a is -1.964 (r^2=0.92). Negative exponential regression equations describing tebuthiuron disappearance in the surface 3 cm of soil under the pellet were developed for each soil and formulation (Table 9).

Tebuthiuron disappearance immediately under the pellet was more rapid in high organic matter soils than in low organic matter soils with both pellet formulations (Figure 1). This more rapid disappearance occurred despite the reduced movement of tebuthiuron in soils with higher organic matter contents. An examinations of the slopes derived from tebuthiuron disappearance data reveals steeper slopes on the high organic matter soils (Table 9). This more rapid disappearance of tebuthiuron in soils with higher organic matter contents may be due to increased microbial activity in those soils (Hurle and Walker 1980).

The influence of soil type on herbicide persistence is poorly understood. Because soil microorganisms are usually involved in degradation of tebuthiuron (Chang and Stritzke 1977), soil organic matter might be expected to have some influence since microbial activity is usually higher in soils with more organic matter (Hurle and Walker 1980). However, adsorption of most herbicides increases with increasing organic matter and since adsorption reduces the herbicide concentration in the soil solution it could potentially reduce degradation. For these reasons, Hamaker (1972) suggested that an increase in organic matter might increase degradation rates in mineral soils up to a limiting value, above which the rate of loss would be retarded. Many of the tebuthiuron residues reported in this study are probably too high for adsorption to play a significant role in limiting degradation rates. However, as concentrations are reduced over time, adsorption of tebuthiuron to clay particles and organic matter may reduce the rate of tebuthiuron degradation.

For this reason, regression equations predicting residue concentrations beyond the time period of the data in this study, would be subject to additional and unknown error.

Results of tebuthiuron analyses indicated significant residue concentration differences following applications of 20 and 40% pellets. This is largely explained by the greater pellet size and concentration of active ingredients in the 40% pellets. The rate of tebuthiuron disappearance was greater with 40% pellets at the Tintic experiments but less at the Ephraim experiment (Table 9). No clear differences in disappearance rates between the two formulations can be determined from these data.

CONCLUSIONS

Vertical and lateral movement, and persistence were influenced by precipitation, clay content, and organic matter content of the soil. Lateral movement of tebuthiuron was less on high organic matter soils compared to low organic matter soils. Tebuthiuron movement away from 40% pellets was greater than from the 20% pellets. Downward movement of tebuthiuron increased with low soil organic matter and more concentrated pellet formulations.

Tebuthiuron residues reported in this study are considerably higher than those reported by other investigators (Garcia and Gontarek 1975, Bovey et al. 1978, Emmerich et al. 1984, Ibarra and Morton 1984). This is probably because the other studies reported tebuthiuron concentrations of random soil samples collected in an area which had received broadcast applications of pellets. These samples undoubtedly included soil immediately under pellets as well as soil from between pellets. The area between pellets would vary with pellet formulation, pellet size, and application rate. This mixture of treated and untreated soil would have lower tebuthiuron residues than soil immediately under pellets. This study reports tebuthiuron residues immediately under and around tebuthiuron pellets. The different sampling approaches, soil characteristics, and climatic conditions of the various studies probably account for much of the variation in tebuthiuron concentrations between this and other sutdies. The sampling approach used in this study should give a more reliable indicator of the amount and distribution of tebuthiuron in soils following application of pelleted material.

Tebuthiuron application rates for big sagebrush control range from 1.1 to 1.6 kg ai/ha, depending on soil texture. An application of 40% tebuthiuron pellets (206 mg each) would represent one pellet per 0.74 m^2 and 0.49 m^2 at 1.1 kg/ha and 1.6 kg ai/ha, respectively. Data from tables 4, 6, and 8 indicate that 40% tebuthiuron pellets influence approximately 20 to 30 cm around each pellet, depending on soil organic matter and clay content. Calculating the area influenced by each pellet and expressing that as a percentage of the soil surface area per pellet yields an approximation of the percent of the soil surface containing tebuthiuron residues. On the Tintic soil containing high soil organic matter, approximately 1,257 cm^2 of soil surface was affected around each pellet. This means that about 17 and 26% of the soil surface was affected by tebuthiuron residues following applications of 1.1 and 1.6 kg ai/ha, respectively (using 40% pellets). Soils with lower organic matter contents would have a larger percentage of the area affected. Tebuthiuron residues, one year after application, were probably sufficient, based on data from other studies (Bovey et al. 1982, Masters and Scifres 1984), to significantly influence establishment of seeded species. Plants growing outside these treated areas may not be influenced by tebuthiuron residues, unless their root systems grow into the treated zone and receive sufficient tebuthiuron to result in growth reduction or death.

Time constraints imposed on this study limited the ability to predict the length of time tebuthiuron residues would be present in the soil. Extrapolation, in time, beyond the present data set is not advisable because of the many variables which can influence the rate of tebuthiuron degradation. However, this data should provide sufficient information to enable resource managers to predict the spacial distribution of tebuthiuron in a variety of soils, following application of pelleted formulations of tebuthiuron. With an understanding of critical minimum residues of tebuthiuron, in a variety of soils and on a variety of plant species, resource managers should be able to more accurately access the potential for problems in seeding efforts following tebuthiuron applications.

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Table 1. Chemical and physical characteristics of soils in which tebuthiuron movement and persistence was monitored near Tintic and Ephraim, Utah, during 1984 and 1985.

Location	Depth (cm)	Textural components			Organic matter (%)	pH
		Sand (%)	Silt (%)	Clay (%)		
Ephraim	0 to 3	39.6	32.9	27.5	1.8	8.2
	3 to 12	32.9	30.8	36.3	1.9	8.2
	12 to 30	34.1	30.0	35.9	1.1	8.4
Tintic						
Low organic matter	0 to 3	35.2	44.9	19.9	1.7	7.8
	3 to 12	27.9	43.9	28.2	1.7	7.8
	12 to 30	28.1	42.4	29.5	1.4	7.8
High organic matter	0 to 3	35.2	45.1	19.7	4.7	7.6
	3 to 12	27.3	44.3	28.4	1.8	7.8
	12 to 30	28.5	42.4	29.1	1.6	7.8

Table 2. Cumulative precipitation totals from the application date to the date of soil collection, at the Ephraim and Tintic, Utah, study areas.

Study area	Days after application	Cumulative precipitation (cm)
Ephraim	20	7.16
	40	16.46
	78	16.51
	189	26.62
	370	50.17
Tintic	37	4.98
	80	8.26
	173	27.08
	350	46.81

Table 3. Average concentrations (ppmw) of tebuthiuron residue in soil at various depths, at four distances from the initial pellet placement, and at various times after application of 20% pellets on April 13, 1984 to soil near Ephraim, Utah[1].

Soil depth (cm)	Time after pellet placement (days)	Distance from tebuthiuron pellet 0 (cm)	10 (cm)	20 (cm)	30 (cm)
0 to 3	20	499.4 a	17.3 e	0.0 h	0.0 h
	40	384.1 b	324.7 b	0.0 h	0.0 h
	78	143.0 c	10.3 f	0.4 h	1.1 h
	189	6.7 fg	0.7 h	1.3 gh	0.7 h
	370	2.3 g	1.4 g	1.1 h	0.4 h
3 to 12	20	0.0 h	5.9 fg	0.0 h	0.0 h
	40	12.3 f	4.7 g	0.2 h	0.0 h
	78	31.2 d	3.4 g	1.1 h	0.0 h
	189	12.5 f	5.7 fg	0.7 h	0.4 h
	370	9.1 f	3.8 g	0.5 h	0.0 h
12 to 30	20	0.0 h	0.0 h	0.3 h	0.0 h
	40	0.0 h	0.2 h	2.5 g	0.0 h
	78	0.2 h	0.5 h	8.3 f	0.0 h
	189	1.3 gh	4.3 g	6.3 fg	0.8 h
	370	1.1 h	2.2 g	2.7 g	0.0 h

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's new multiple range test.

Table 4. Average concentrations (ppmw) of tebuthiuron residue in soil at various depths, at four distances from the initial pellet placement and at various times after application of 40% pellets, on April 13, 1984, to soil near Ephraim, Utah[1].

Soil depth (cm)	Time after pellet placement (days)	Distance from tebuthiuron pellet 0 (cm)	10 (cm)	20 (cm)	30 (cm)
0 to 3	20	1,254.1 a	25.4 e	0.4 ij	0.0 j
	40	982.1 b	22.3 e	0.0 j	0.0 j
	78	328.2 c	17.7 ef	0.0 j	0.0 j
	189	29.1 e	4.2 g	0.0 j	0.0 j
	370	11.9 f	3.1 gh	0.0 j	0.0 j
3 to 12	20	31.3 e	2.6 gh	0.5 ij	0.0 j
	40	57.7 d	3.1 gh	0.0 j	0.0 j
	78	52.0 d	11.3 f	0.0 j	0.4 ij
	189	14.2 f	17.8 ef	4.9 g	0.5 ij
	370	1.7 h	1.7 h	1.4 hi	1.1 i
12 to 30	20	0.0 j	1.4 h	0.0 j	0.0 j
	40	1.3 h	6.0 fg	1.1 i	0.4 ij
	78	0.5 ij	11.2 f	2.6 gh	0.1 i
	189	0.3 j	11.4 f	10.1 f	9.8 f
	370	2.9 gh	0.2 j	8.9 f	5.4 g

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's new multiple range test.

Table 5. Average concentrations (ppmw) of tebuthiuron residue in soil at various depths, at four distances from the initial pellet placement and at various times after application of 20% pellets, on May 5, 1984, to low organic matter soil near Tintic, Utah[1].

Soil depth (cm)	Time after pellet placement (days)	Distance from tebuthiuron pellet 0 (cm)	10 (cm)	20 (cm)	30 (cm)
0 to 3	37	573.5 a	136.5 b	0.2 g	0.0 h
	80	168.5 b	21.1 c	2.6 f	1.2 fg
	173	24.0 c	9.6 d	3.0 f	0.9 fgh
	350	4.9 e	3.7 e	2.1 f	0.4 gh
3 to 12	37	23.2 c	13.7 d	2.1 f	0.2 gh
	80	32.4 c	2.6 f	2.3 f	0.3 g
	173	12.0 d	20.7 c	1.9 f	0.6 g
	350	7.1 e	4.4 e	0.8 g	0.4 g
12 to 30	37	0.0 h	14.2 d	1.7 f	0.0 h
	80	9.7 d	5.1 e	2.9 f	0.0 h
	173	4.3 e	6.5 e	2.7 f	0.1 h
	350	2.8 f	1.3 f	0.4 g	0.1 h

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's new multiple range test.

Table 6. Average concentrations (ppmw) of tebuthiuron residue in soil at various depths, at four distances from the initial pellet placement and at various times after application of 40% pellets, on May 5, 1984, to low organic matter soil near Tintic, Utah[1].

Soil depth (cm)	Time after pellet placement (days)	Distance from tebuthiuron pellet			
		0 (cm)	10 (cm)	20 (cm)	30 (cm)
0 to 3	37	1,843.1 a	93.0 cd	1.6 hi	0.4 ij
	80	383.5 b	38.9 e	5.2 g	2.2 h
	173	38.2 e	38.8 e	5.1 g	1.8 hi
	350	23.6 e	23.0 e	4.4 gh	1.0 i
3 to 12	37	70.4 d	23.9 e	5.6 g	0.3 j
	80	24.2 e	23.8 e	10.2 fg	2.1 h
	173	14.0 f	13.4 f	6.3 g	1.7 hi
	350	2.7 h	5.8 g	2.4 h	1.0 i
12 to 30	37	14.1 f	14.2 f	0.0 j	0.0 j
	80	12.1 f	10.2 fg	0.7 i	0.0 j
	173	6.9 g	7.0 g	5.1 g	2.3 h
	350	6.0 g	5.8 g	4.2 gh	3.1 h

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's new multiple range test.

Table 7. Average concentrations (ppmw) of tebuthiuron residue in soil at various depths, at four distances from the initial pellet placement and at various times after application of 20% pellets, on May 5, 1984, to high organic matter soil near Tintic, Utah[1].

Soil depth (cm)	Time after pellet placement (days)	Distance from tebuthiuron pellet 0 (cm)	10 (cm)	20 (cm)	30 (cm)
0 to 3	37	768.1 a	26.5 ef	0.0 j	0.0 j
	80	298.0 b	178.5 c	0.0 j	0.0 j
	173	32.1 e	23.3 f	0.4 j	0.0 j
	350	3.1 h	0.9 i	0.0 j	0.0 j
3 to 12	37	42.3 e	28.5 ef	0.0 j	0.0 j
	80	77.0 d	38.1 e	0.0 j	0.0 j
	173	7.3 g	15.0 f	0.4 j	0.3 j
	350	2.0 hi	1.7 i	0.1 j	0.0 j
12 to 30	37	0.2 j	0.0 j	0.0 j	0.0 j
	80	3.3 h	0.0 j	0.0 j	0.0 j
	173	1.7 i	2.8 h	0.0 j	0.0 j
	350	0.2 j	0.2 j	0.0 j	0.0 j

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's new multiple range test.

Table 8. Average concentrations (ppmw) of tebuthiuron residue in soil at various depths, at four distances from the initial pellet placement and at various times after application of 40% pellets, on May 5, 1984, to high organic matter soil near Tintic, Utah[1].

Soil depth (cm)	Time after pellet placement (days)	Distance from tebuthiuron pellet 0 (cm)	10 (cm)	20 (cm)	30 (cm)
0 to 3	37	1,652.1 a	865.3 c	6.2 jk	0.0 m
	80	691.4 b	238.3 e	5.1 k	0.0 m
	173	55.0 g	41.3 gh	2.6 kl	0.0 m
	350	8.1 j	8.9 j	1.1 l	0.0 m
3 to 12	37	343.1 d	249.2 e	20.2 i	0.0 m
	80	130.0 f	3.4 k	5.1 k	0.0 m
	173	43.3 gh	21.2 i	6.2 jk	0.0 m
	350	10.1 j	4.3 k	1.8 l	0.0 m
12 to 30	37	0.0 m	0.0 m	0.0 m	0.0 m
	80	0.4 lm	0.6 lm	1.1 l	0.0 m
	173	3.2 k	1.9 l	1.4 l	0.0 m
	350	0.9 l	0.4 lm	0.0 m	0.0 m

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's new multiple range test.

Table 9. Exponential regression equations describing tebuthiuron disappearance in the surface 3 cm of soil under the point of pellet placement at study areas near Ephraim and Tintic, Utah. All equations take the form of $Y=bX^a$, where Y is ppmw of tebuthiuron and X is days after pellet placement.

Location	Pellet formulation (ai)	b	a	r^2
Ephraim	20	2.85×10^5	-1.893	0.9363
	40	4.07×10^5	-1.753	0.9507
Tintic				
Low organic matter	20	1.66×10^6	-2.159	0.9918
	40	2.77×10^6	-2.056	0.9582
High organic matter	20	9.49×10^6	-2.490	0.9639
	40	1.76×10^7	-2.456	0.9666
All sites combined	20	7.57×10^5	-2.032	0.9227
	40	1.43×10^6	-1.964	0.9212

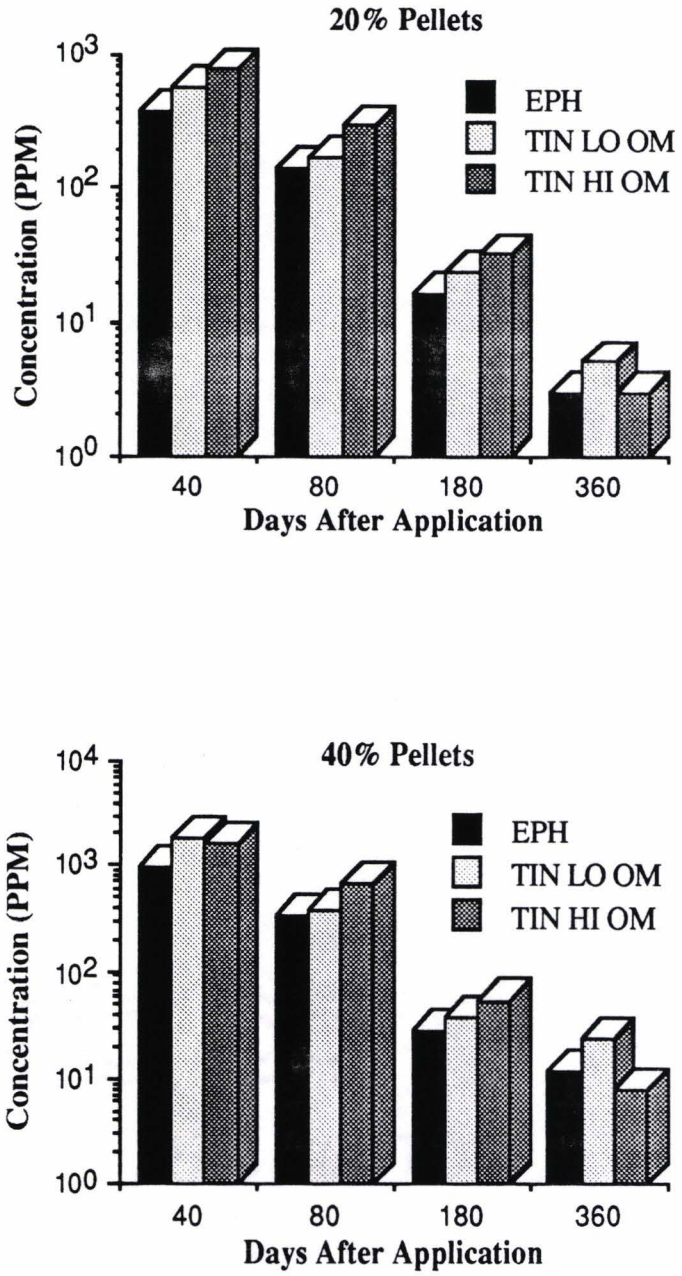

Figure 1. Tebuthiuron concentration in the surface 3 cm of soil under the pellet in the Ephraim (EPH), Tintic low organic matter (TIN LO OM) and Tintic high organic matter (TIN HI OM) soils.

RECOMMENDATIONS FOR ADDITIONAL RESEARCH

This research was designed to evaluate the movement and persistence of tebuthiuron residues in intermountain soils. This information is required for environmental assessments of tebuthiuron applications. The presence of various amounts of tebuthiuron in the soil is not directly comparable to biological activity, when several soil types are considered. Soils with identical tebuthiuron concentrations may have very different biological effects. Increased clay and organic matter contents will decrease tebuthiuron activity on vascular plants. Different plant species also have varying susceptibilities to tebuthiuron. Effects of tebuthiuron concentrations on individual plant species may be expected to vary between seedlings and mature plants. For tebuthiuron soil-residue data to be directly useful to resource managers interested in reseeding, relationships between soil organic matter, clay content and toxicity to important plant species must be better understood.

ACTUAL COSTS

	NAPIAP FUNDS[2]	BYU FUNDS
(A) SALARIES AND WAGES		
Principal Investigator	$ 6,524.76	$ 9,398.00
Students	4,500.42	
Non-Students	3,949.55	
Total Salaries and Wages	$14,974.73	$ 9,398.00
(B) FRINGE BENEFITS (12% Salaries And Wages)	$ 1,796.97	$ 1.127.76
Total Salaries, Wages and Benefits	$16,771.70	$10,525.76
(C) EQUIPMENT AND SUPPLIES	$ 8,382.67	$ 352.25
(D) CAPITAL EQUIPMENT	$ 763.52	
(E) TRAVEL	$ 2,601.80	
(F) OTHER COSTS		
Publication Costs	$ 385.00	
(G) TOTAL DIRECT COSTS (A, B, C, E, F)	$28,141.17	$10,878.01
(H) TOTAL INDIRECT COSTS		
Indirect Cost Recovery (42%)	$ 0.00	$ 4,568.76
(I) TOTAL COSTS (D, G, H)	$28,141.17	$15,446.77

[2]Brigham Young University received these funds from the Intermountain Forest and Range Experiment Station as a Cooperative Agreement (USDA 22-C-4-INT-46).

PLANS FOR PUBLICATION

A manuscript entitled "Tebuthiuron Distribution in Rangeland Soils Following Application of Pelleted Material" will be submitted to the Journal of Environmental Quality by May 1, 1986. In March 1986 a presentation entitled "Tebuthiuron Persistence in Intermountain Soils" will be presented to the Western Society of Weed Science in San Diego, California and published in the procedings of that meeting.

POTENTIAL PATENTS

No potential patents resulted from this research and none are foreseen.